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Procedia Engineering 113 (2015) 57 – 61

**Procedia  
Engineering**[www.elsevier.com/locate/procedia](http://www.elsevier.com/locate/procedia)

International Conference on Oil and Gas Engineering, OGE-2015

# Assessment of soil biocorrosion severeness on the pipeline locations

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## Abstract

In assessing the soil corrosion activity on the pipeline locations caused by a combination of factors, the severity of microbiological indicators (number of sulfur cycle bacteria) was determined. Soils microbiological testing revealed the absence of sulfate-reducing bacteria and detected thiobacteria in different concentrations. Severity assessment of the soils biocorrosion activity allowed to identify a sufficiently high level of soil samples having a moderately corrosive activity. Correlation between soils biocorrosion activity criterion index and quantitative content thiobacteria of the soil was identified. The results suggest that thiobacteria play an important role in the corrosion development in underground metal pipelines and use the findings in validation preventive trends.

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Peer-review under responsibility of the Omsk State Technical University

**Keywords:** biocorrosion activity; soils; microbiological investigations; sulfate-reducing bacteria; thiobacteria

## 1. Introduction

The main cause of accidents on the field facilities and main gas and oil pipelines, according to [1] is corrosion, with more than 50% of the pipelines corrosion damage associated with biocorrosion.

Oilfield equipment failure analysis [2-4] has shown that the greatest danger in biocorrosion are bacteria, as they multiply rapidly and easily adapt to the environment, taking an active part, first, in the deterioration process of seal coat, and then gas and oil pipelines metal objects. Main microbiota representatives of the soil, causing galvanic corrosion, are the sulfur cycle bacteria (thionic and sulfate-reducing) [5-8]. One side, biocorrosion is an independent

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metal fracture, on the other hand, it affects the electrochemical processes at the metal surface, which often results in accelerating other types of corrosion, in particular it may be one of the factors leading to stresscorrosion [9].

Microbial colonization of metal structures takes place through the formation of biofilms, which can dramatically change the corrosion behavior of metal, for example as a result of vital activity of sulfate-reducing bacteria the corrosive destruction is recorded despite cathodic polarization of the protected structures to minus 0.85 V (according to copper sulphate electrode reference) [10].

Overview of the different biodegradation processes and composition of microorganisms forming the biofilm community is presented in [11-15]. The most potentially corrosively active microorganisms of the genus *Thiobacillus* are *Thiobacillus thioparus*, *Thiobacillus oxidans*, *Thiobacillus ferrooxidans* species [16]. Members of the genus are gram-negative rod-shaped microorganisms of 0.4-0.5x1.0-4.0  $\mu\text{m}$ . Most of them are mobile because of one or a bunch of flagella. When identifying thiobacteria the growth depending on the ambient temperature, pH, presence of molecular oxygen, the use of organic compounds capable of sulfur compounds oxidizing are considered. Microorganisms of the genus *Thiobacillus* are capable of oxidizing several sulfur compounds (sulfide, thiosulfate, tetrathionate, carbon disulfide, thiocyanate, carbon sulfur oxide, molecular sulfur). Most thiobacteria use sulfates for biosynthetic processes. Thiobacteria molecular oxidize molecular sulfur and reduce its compounds, resulting in the formation of sulfate and the media reaction reduction. Sulfate-reducing bacteria belonging to the genus *Desulfotomaculum*, which play an important role in the occurrence of metals corrosion (*Desulfotomaculum orientis* and *Desulfotomaculum nigrificans*), are obligate anaerobes, chemolithoheterotroph microorganisms. They are not able to assimilate carbon dioxide autotrophically. They need organic substances for their growth – lactate, pyruvate, malate, formate, choline, primary alcohols, aminoacids, carbohydrates, petroleum hydrocarbons. The end product of anaerobic respiration is hydrogen sulfide.

It is also necessary to consider the effect of environmental conditions on the biofilms adhesion to metal in operation [17] and the impact of microorganisms on each other, which can be both symbiotic and antagonistic, and therefore we can speak not only of the catalyst, but of inhibiting action of microorganisms on corrosion processes [6, 18]. Thus, one of the most urgent tasks is to develop a comprehensive approach to assessing biocorrosion activity of soils on the oil and gas pipelines locations.

## 2. Study subject

This work is devoted to the study of sulfur cycle bacteria (thionic and sulfate-reducing) in the oil and gas pipelines locations on the territory of the Khanty-Mansiisk autonomous district – Yugra. The aim of our study was to assess soil corrosion activity in the area gas pipeline location, due to the several factors, and to determine the microbiological indicators activity.

In the research we used soils biocorrosion activity assessment on a range of microbial (amount of sulfur cycle bacteria) and physical and chemical parameters (total sulfur and iron concentration, pH, resistivity) in soil samples adjoining to the surface of underground pipelines, and the relationship of these indicators with a specific soil electrical resistance.

## 3. Methods

Soil sample collection near the pipeline was carried out at the time of pitting according to the following scheme: at a depth of 0.5 m, at the top, side, bottom side of the pipeline, along the pit wall, at a distance of 10 m from the pipeline at a depth of 0.5 m (control). For microbiological studies we prepared soil suspension in proportion: 10 g of soil was added to 90  $\text{cm}^3$  of sterile tap water. Soil suspension was shaken for 30 min. on shaking apparatus in the mode of 100 rev/min. In the study of the sulfate-reducing bacteria amount a Postgate sterile nutrient solution was added into the test tube with soil dilution. The test tubes were placed in a thermostat at a temperature of 28<sup>0</sup> C and kept for 20 days. To determine the amount of autotrophic thiobacteria we used soil suspension inoculation in the test tube with Beijerinck nutrient solution and incubate at a temperature of 28<sup>0</sup> C for 7 days. The amount of bacteria in one gram of soil was found out by identifying the number of bacteria in 1 ml of the soil suspension, taking into account the moisture coefficient. Quantitative bacterial content of the soil was expressed by logarithm (*Ig*) concentration value per gram of substrate. We identified criteria of biocorrosion activity of soils (CBA) due to the

combined effect of various factors of corrosion. When interpreting the results of the study soils were divided into potentially severe ( $CBA < 1.5$ ), slightly severe ( $1.5 < CBA < 4.0$ ), moderately severe ( $4.0 < CBA < 7.0$ ), severe ( $7.0 < CBA < 10.0$ ), very severe ( $10.0 < CBA$ ). Biometric analysis was performed using STATISTICA-6, BIOSTATISTICA, Microsoft Excel software features. In all statistical analysis procedures, the critical level of significance  $p$  was assumed to be 0.05. The values of  $p$  can be ranked by 3 levels achieved at statistically significant difference:  $p < 0.05$ ;  $p < 0.01$ ;  $p < 0.001$ .

#### 4. Results and discussion

Studies on the soils biocorrosion activity allowed to identify three groups of samples: slightly severe, moderately severe and potentially severe.

Table. 1 shows the results of soils biocorrosion activity

Table 1. Soil analysis in the studied samples according to biocorrosion activity criteria.

Samples	Samples amount	Detection frequency P (%)	CBA M $\pm$ m
Potentially severe	3	10.34	0.86 $\pm$ 0.20
Moderately severe	16	55.17	2.44 $\pm$ 0.19
Slightly severe	10	34.48	4.65 $\pm$ 0.20

There were no severe and highly severe soil samples. Samples with slightly severe soil (55.17% of cases) prevailed, with the biocorrosion activity criterion value ( $2.44 \pm 0.19$ ), a high enough soil samples detection frequency with moderately severe biocorrosion activity was marked ( $4.65 \pm 0.20$ ). Microbiological soil testing for the bacteriological identification of sulfate-reducing and thiobacteria showed no sulfate-reducing bacteria in all samples and identified thiobacteria in different concentrations. The absence of sulfate-reducing bacteria in the soil samples can be connected with unfriendly pH environment to their development. To characterize the effect of environmental factors a soil pH was measured, given its effect on the biodegradation process, and amount of soil thiobacteria was recorded. The results characterize the average values of these indicators and established criteria of soils biocorrosion activity of  $3.04 \pm 0.27$  (Table. 2). The presence of the *Thiobacillus* genus microorganisms in the samples at a concentration of  $3.54 \pm 0.11$  CFU/g of soil was identified. Acidic and weakly acidic reaction of soil environment can be explained by thiobacteria vital functions. The oxidative activity of these organisms indicates their high potential in the formation of corrosively active metabolites (sulfuric acid, elemental sulfur). Thiobacteria have an accelerating effect on the steel corrosion, the oxidation end product are sulfates and sulfuric acid, causing a pH reduction.

Table 2. Complex assessment indicators of soils biocorrosion activity.

Indicators	Samples amount	M $\pm$ m
CBA (ka)	29	3.04 $\pm$ 0.27
Soil pH	29	5.43 $\pm$ 0.04
Amount of thiobacteria	29	3.54 $\pm$ 0.11

A strong correlation ( $R=0.97$ ) of the soil biocorrosion activity criteria indicator and the soil thiobacteria amount was determined.

The studies have shown the significant differences in the amount of thiobacteria and free iron in the soil samples ( $T=97.00$ ,  $Z=2.606$ ,  $p=0.009$ ) Fig.1. At the same time we found a direct correlation of medium strength concentrations of bacteriologically identified bacteria and content of iron in the soil ( $R_s 0.5579$ ,  $p=0$ ).

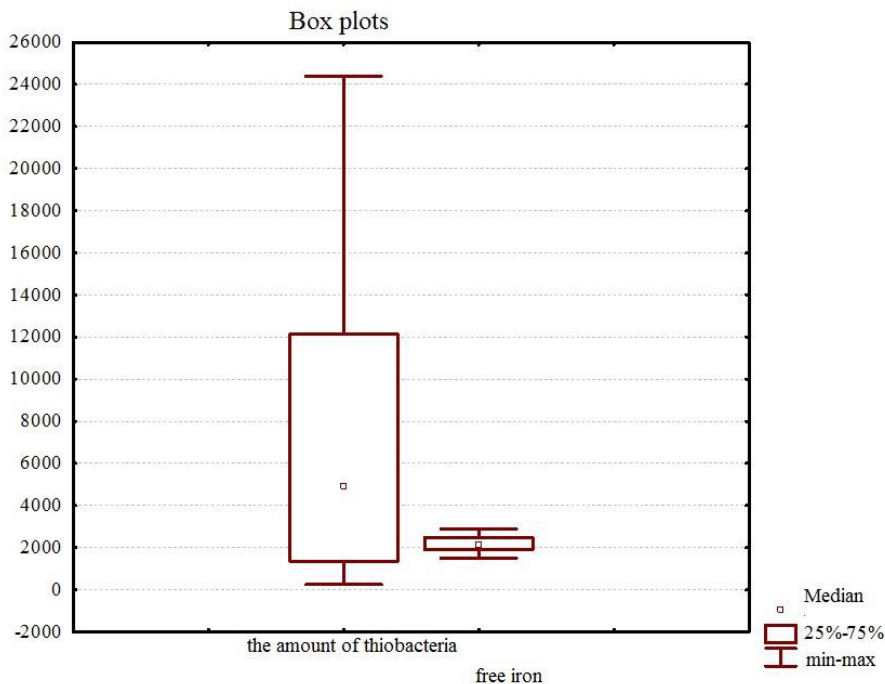


Fig. 1. Thiobacteria and iron amount in soils.(X axis shows thiobacteria, free iron in the soil; axis Y shows thiobacteria concentration in 1 gram of soil, free iron (mg/kg).

The results serve as an assessment criteria of soil biocorrosion activity. The severity assessment of the soils biocorrosion activity allowed to identify three groups of samples – slightly severe, moderately severe and potentially severe with high soil detection frequency, having a moderately severe activity.

## 5. Conclusion

In ecological conditions, characterized by a sufficient amount of free sulfur or its reduced compounds, thiobacteria can contribute to corrosion formation. Thus, we can conclude that the sulfur-oxidizing thiobacteria play an important role in the corrosion development of underground metal pipelines and we can use the findings in the validation of the main preventive ways. In biocorrosion the destruction occurs locally and at high speed, with one of the problems being the difficulty of detecting, forecasting and eliminating [8.10]. Given that the biocorrosion effects are difficult to differentiate from symptoms of other types of corrosion, analysis of the soils corrosion activity should be carried out with the microbiologists participation.

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